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FACTORS AFFECTING JACK PINE CONE AND SEED SUPPLY AFTER HARVESTING IN NORTHWESTERN ONTARIO

by

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ABSTRACT

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Twenty-three cutovers formerly dominated by jack pine (*Pinus banksiana*) and harvested since 1985 were sampled in northwestern Ontario in 1989 for numbers and distribution of jack pine cones within 30 cm of ground level. Effects of stand age, harvesting season, harvesting method (full-tree vs tree-length), and seedbed condition (with or without site preparation) were evaluated.

Numbers of cones ranged from 8 800 - 126 800 cones/ha, depending on the combination of the above variables. Harvesting older stands (>80 years) resulted in higher numbers of cones in cutovers compared to harvesting younger (<80 years) stands. Summer logging left more cones in the cutover than did winter logging, but lack of data for tree-length logging in the winter restricts the strength of this observation. Tree-length harvesting tended to leave more cones behind in the cutovers than did full-tree harvesting, but there was no consistent trend. Site preparation following logging tended to reduce the number of cones in a cutover, regardless of harvesting season, harvesting method or stand age.

An equation was developed to estimate two-year jack pine seedling densities from post-harvest numbers of jack pine cones. In addition, minimum stocking standards were compiled from published data to relate numbers of cones in cutovers to stocking of two-year-old jack pine seedlings. When this equation and a minimum stocking standard of 60% based on 10 cones per 4 m^2 quadrat were applied to the data in this study, only three of 11 treatment combinations had a sufficiently high density and stocking to assume a high probability of a successful new stand. These three treatments were full-tree summer logging in old stands with or without site preparation, and tree-length summer logging in old stands without site preparation.

KEYWORDS: Pinus banksiana, full-tree, tree-length, cone, seedling, natural regeneration.

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INTRODUCTION

In northwestern Ontario, much of the natural forest is fire-origin jack pine (*Pinus banksiana*), commonly growing in mixed stands with black spruce (*Picea mariana*) and trembling aspen (*Populus tremuloides*) (Sims et al. 1989). These stands are usually harvested by the clearcut method using tree-length logging, whereby each tree is limbed and the crown lopped before removal of the bole to roadside. Artificial regeneration of these sites usually includes some degree of site preparation followed by aerial seeding of 35 - 50,000 jack pine seeds/ha, or planting of 1500 - 3500 trees/ha.

Full-tree harvesting (removal of complete trees to roadside before crown and branch removal) is becoming more popular as a harvesting method. Compared to tree-length harvesting, full-tree harvesting reduces the amount of slash in cutovers. As a result, fewer cones may be left on-site to contribute seeds to the new stand. To date, it is unclear to what extent this reduction of cone-bearing slash may affect post-harvest stocking levels of jack pine and impact upon subsequent aerial seeding or planting requirements.

To address this concern, an extensive survey was undertaken in 1989 to quantify cone numbers and distribution on cutovers resulting from harvesting jack pine stands.

METHODS

Field Sampling

Twenty-three cutovers were sampled across northwestern Ontario (Figure 1). Dry to fresh mineral soil sites formerly dominated by jack pine (>70%) and harvested within the last five years (since 1985) were selected for sampling.

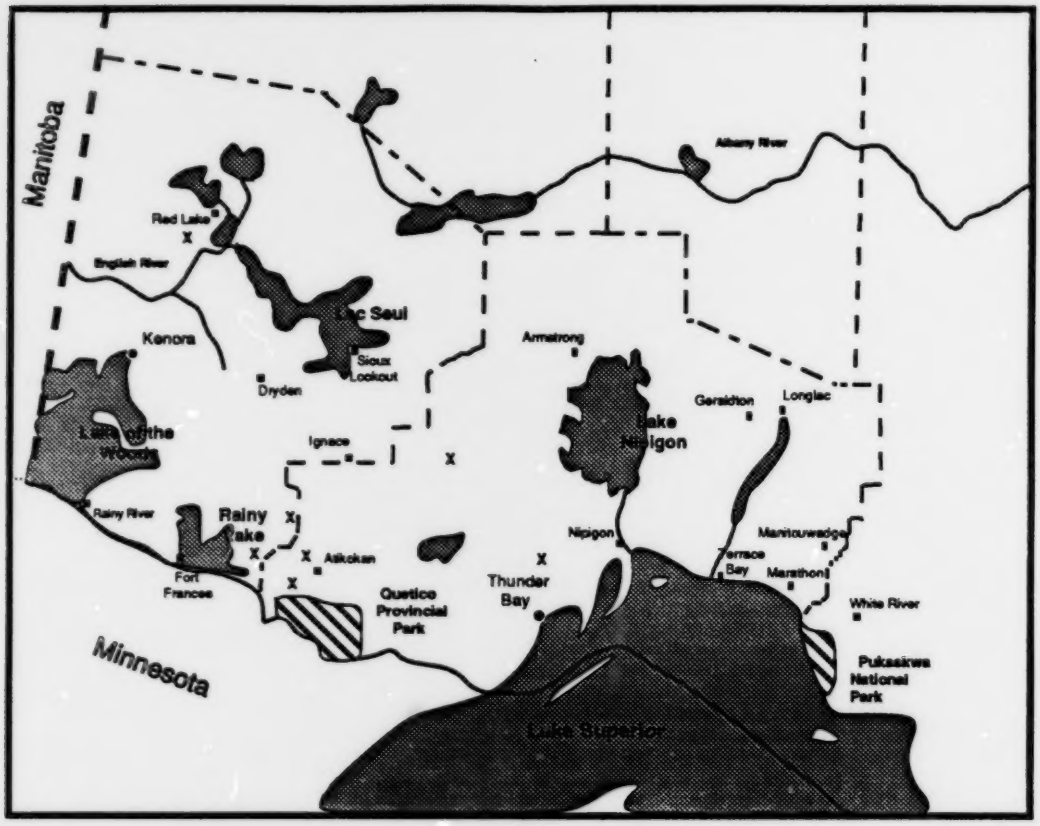

Figure 1. Study area and approximate location of sample sites (X).

Treatments were:

(1) harvesting method: full-tree vs tree-length.

(2) stand age: <80 years vs >80 years. Eighty years was chosen as a reference age because it coincides with class boundaries in the Forest Resource Inventory (FRI) database. Actual stand ages ranged from 47 to 117 years.

(3) harvesting season: spring, summer, and fall vs winter.

(4) seedbed condition : with or without site preparation. Twelve of the 23 cutovers were site prepared with either barrels and chains, disc trenchers, or Bracke. The remaining 11 cutovers were not site prepared.

Depending on cutover size, between two and 12 clusters (replications) of five, 1 m X 1 m quadrats were randomly located within each cutover (Figure 2). Areas within the selected cutovers that had been obviously less than 70% jack pine (e.g. trembling aspen clumps or low swampy areas) were avoided. In addition, areas with excessive machine disturbance (skidtrails) were not sampled.

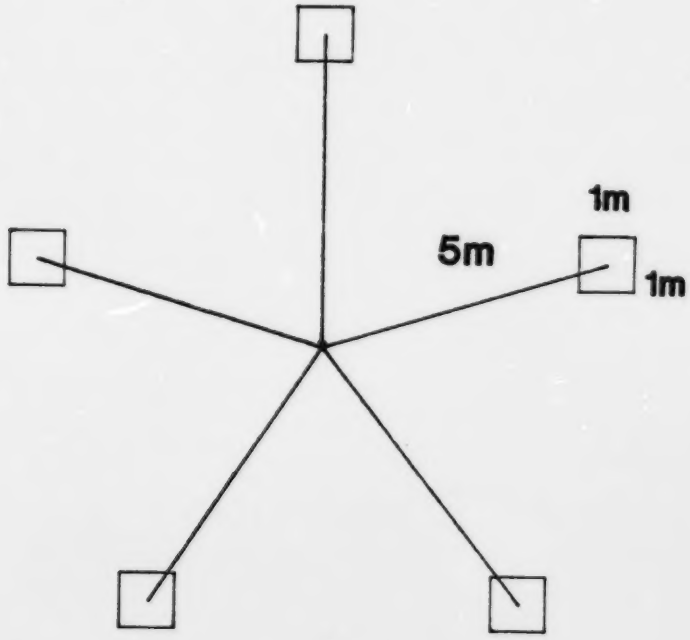

Figure 2. Layout of the 5 - 1 m^2 quadrats within a cluster. Quadrats were located five metres from plot centre at 0, 72, 144, 216, and 288 degrees azimuth.

Within each quadrat, all cones lying on the ground or attached to branches within 30 cm aboveground were counted on a cumulative tally (Walker and Sims 1984). Stand age from forest covertype maps was verified by ring counts on stump cross-sections.

Data Analysis

Standard deviations and variances were generated to assess the level of variability within the data set. Cluster means were computed and a Student's t-test was used to compare treatment means. Homogeneity of variance using an F-test was used to determine the correct t-test (Snedecor and Cochran 1967).

Much variability was encountered. Some clusters of quadrats had no cones at all, while other clusters had very high cone numbers due to one or more quadrats having a tree crown. A very large sample size would be required to reduce the variance associated with sampling this kind of wide distribution. In the absence of such a large data set, any cluster whose mean number of cones was beyond three standard deviations of its corresponding treatment mean was excluded from analysis. Five of a total of 133 clusters were eliminated from the dataset as a result of this procedure.

RESULTS

Eleven treatment combinations were sampled and are ranked by cone abundance in Table 1. The number of cutovers sampled for each treatment combination is low, reflecting the extensive nature of this survey. In addition, because tree-length logging during winter is not a common practise in northwestern Ontario, no cutovers were sampled for this treatment.

Number of Cones

Age Effects

Stand age at the time of harvest affected the number of jack pine cones left behind in the cutovers. Of the 11 treatment combinations sampled, five were in young stands (<80 years old at time of harvest) and had a mean of

approximately 12 000 cones/ha, and six were in old stands (>80 years old at time of harvest) with a mean of over 50 000 cones/ha. Five of these six old stands resulted in the highest numbers of cones after logging, irrespective of other variables such as harvesting season, harvesting method, or seedbed condition.

Table 1. Mean number of jack pine cones in cutovers (000's/ha) in northwestern Ontario as affected by season of harvest, harvesting method, stand age and seedbed condition.

Treatment	000's/ha	sd	n	c
S, TL, >80, NSIP	126.8	46.1	5	2
S, FT, >80, SIP	49.2	20.4	8	1
S, FT, >80, NSIP	49.0	27.1	13	3
S, TL, >80, SIP	33.2	27.8	19	2
W, FT, >80, NSIP	27.8	16.7	20	4
S, FT, <80, NSIP	17.6	7.1	8	1
S, TL, <80. SIP	15.8	10.9	11	2
W, FT, >80, SIP	15.0	11.1	10	2
S, FT, <80, SIP	9.6	8.5	12	3
S, TL, <80, NSIP	8.8	9.3	5	1
W, FT, <80, SIP	8.8	2.6	17	2

S = summer logged W = winter logged
TL = tree-length harvesting FT = full-tree harvesting

<80 = stand age less than 80 years at time of harvest
>80 = stand age greater then 80 years at time of harvest

SIP = site prepared NSIP = not site prepared
sd = standard deviation n = number of clusters
c = number of cutovers sampled.

Means joined by vertical lines are not significantly different at alpha = 0.05 level of probability.

Harvesting Season Effects

Winter logging resulted in less than one-half the number of cones in cutovers compared to summer logging (17 200 vs 38 800 cones/ha, respectively). However, the small number of samples from winter logged areas restricts the strength of this result. Treatments with the four highest cone numbers were all the result of summer logging.

One particular treatment combination (tree-length logging of old stands during summer without site preparation), left an average of 126 800 cones/ha, significantly higher than all other treatment combinations. Summer logging of old stands with any other combination of harvesting system or site preparation resulted in the next highest numbers of cones, with a range of 33 200 - 49 200 cones/ha, with no significant differences among them (Table 1).

Harvesting Method Effects

No consistent trends emerged from the data regarding effects of harvesting method alone on cone numbers. Full-tree harvesting left from 8 800 to 49 200 cones/ha, while tree-length harvesting left from 8 800 to 126 800 cones/ha in the cutovers. In some treatments, with other variables held constant, full-tree harvesting left more cones on-site than tree-length harvesting, while in other cases the opposite was true. Other variables such as stand age and harvesting season would appear to be influencing effects of harvesting method alone on cone abundance in cutovers.

Seedbed Condition Effects

In general, site preparation following logging reduced numbers of cones in the height region sampled (30 cm from ground level), regardless of harvesting season, harvesting method or stand age. For example, old stands logged tree-length during summer had 126 800 cones/ha without site preparation but only 33 200/ha with site preparation, a statistically significant decrease. Similarly, old stands logged full-tree during winter had 27 800 vs 15 000 cones/ha without and with site preparation, respectively, although this difference was not statistically significant (Table 1).

In contrast to this trend, site preparation following full-tree harvesting in summer, regardless of stand age, did not have a significant impact on numbers of cones. In old stands for example, cone numbers were almost identical (49 200 vs 49 000 /ha) with and without site preparation, respectively. In young stands, site preparation decreased cone numbers by 45% (from 17 600 to 9 600 cones/ha), a substantial but not statistically significantly decline (Table 1).

Distribution of Cones

In a conventional regeneration survey, both stocking and density of seedlings are tallied (Chaudry 1981). Both pieces of information are needed to properly assess post-cut stand condition because the distribution of seedlings across an area (stocking) is just as important to know (sometimes more important) as total numbers (density).

The identical concept can be applied to distribution of cones across a cutover. Furthermore, if a relationship between cone numbers and/or distribution to subsequent seedling density and/or stocking can be

established, it may be possible to prioritize regeneration activities much sooner after harvesting than is now the case.

Table 2 is a summary of our data based on minimum stocking standards of 1, 5 (from Lyon and van Nooten 1958) and 10 cones per quadrat. Although the data were originally collected from five, 1 m^2 quadrats per cluster, data in Table 2 are based on the standard plot size of 4 m^2 for regeneration surveys, using the transformation equation provided by Chaudry (1981).

Table 2. Jack pine cone stocking (%) in cutovers in northwestern Ontario as affected by minimum stocking standards, season of harvest, harvesting method, stand age and seedbed condition.

Treatment	SIP			NSIP			TOTAL		
	1	5	10	1	5	10	1	5	10
	%			%			%		
S, TL, <80	76	50	43	72	16	16	75	40	34
S, TL, >80	91	71	40	100	100	92	92	77	52
S, FT, <80	87	21	14	100	67	43	91	38	25
S, FT, >80	100	100	67	100	78	61	100	85	63
W, FT, <80	82	40	10	nd	nd	nd	82	40	10
W, FT, >80	67	54	21	91	63	54	84	61	44

1, 5, and 10 are minimum number of cones/ 4 m^2 quadrat
SIP = site prepared NSIP = not site prepared
S = summer logged W = winter logged
TL = tree-length harvesting FT = full-tree harvesting

<80 = stand age less than 80 years at time of harvest
>80 = stand age greater then 80 years at time of harvest
nd = no data

Based on a minimum of one cone per 4 m^2 quadrat, cone stocking (distribution) was generally high, ranging from 67 to 100%. The lowest stocking value (67%) resulted from winter full-tree logging of old stands followed by site preparation. This is the same combination that resulted in the lowest density (number) of cones for old stands (15 000 cones/ha).

Percent stocking declined if a minimum of 10 cones per quadrat was used as the stocking threshold. In this case, stocking ranged from 10 to 92%. It is interesting to note that 92% stocking resulted from tree-length summer logging in old stands without site preparation, the exact combination that yielded the highest numbers of cones, 126 800 cones/ha (Table 1).

DISCUSSION

Cone and Seed Supply (Pre-Harvest)

Jack pine produces good seed crops every three to four years, with light crops in the intervening years (Fowells 1985). In 28 to 80-year-old jack pine stands in northeastern Ontario, Baker (1980) reported an average annual cone production of 24 cones/tree/year.

Roe (1963) estimated that uncut stands of 40 and 70 to 80-year-old jack pine in northern Minnesota contained approximately 33 000 and 52 300 cones/ha, respectively. In that same report, he stated that thinning a 40-year-old jack pine stand more than doubled cone production from 33 000 to 71 300 cones/ha.

From a survey of jack pine stands in northeastern Ontario, Baker (1980) reported an increased number of cones and seeds per tree associated with an increase in tree age and a reduction in stocking.

Cone and Seed Supply (Post-Harvest)

Following a winter cut to a diameter breast height limit of 19 cm in a mature jack pine stand near Pembroke, Ontario, Noakes (1946) reported an astounding 864 500 cones/ha in the cutover. He counted all cones, sometimes in slash piles over two metres thick, and not just those cones within 30 cm of the ground. In a study of jack pine seed dispersal from slash in southeastern

Manitoba, Walker and Sims (1984) reported average cone numbers within 30 cm of the ground surface of approximately 239 000 cones/ha.

In our study, cone densities ranged from 8 800 to 126 800/ha, and are low compared to these published values.

Age Effects

Results from this study concur with the reported trend for stand age, older stands (>80 years) having higher post-harvest cone numbers than younger stands (<80 years). Averaged across all treatments regardless of harvesting season, harvesting method, or seedbed condition, cutovers originating from old stands had an average of 50 200 cones/ha compared to 11 200 cones/ha after harvesting young stands.

Increased cone supply per tree at older ages (larger tree diameters and crowns) has been reported by Baker (1980). In addition, with the tendency of older stands to be less dense than younger stands (Plonski 1974), branches may tend to be longer, thicker, and perhaps more likely to break off during harvest.

Harvesting Season Effects

It was assumed that winter logging would result in higher cone numbers in cutovers compared to summer logging because of more breakage from frozen branches. Our data show the opposite trend, with an average of 17 200 and 38 800 cones/ha in winter and summer logged areas, respectively. Although the lack of data from winter logged areas may partly explain this rather unexpected result, snow-covered cutovers may reduce the impact of sharp bumps and jolts (and breakage) when tree crowns are dragged to roadside.

For full-tree harvested areas only, our data allow for three comparisons between harvesting season where stand age and harvesting method remain constant. In all three cases, winter harvesting resulted in fewer cones left behind in the cutovers compared to summer harvesting. For example, summer logging in old stands without site preparation resulted in 49 000 cones/ha compared to 27 800 cones/ha in winter. With site preparation, numbers declined to 9 600 and 8 800 cones/ha, respectively.

Harvesting Method Effects

It was assumed that tree-length harvesting would leave more cones behind in the cutover than full-tree harvesting. Results from this study show this trend but also indicate that the abundance of cones in a cutover does not seem to be simply a result of harvesting method alone.

Across all treatments, the average number of cones left behind after tree-length logging was approximately 46 000/ha, compared to 25 300/ha for full-tree harvesting. However, the range of variability around these means resulted in no statistically significant difference between them.

Seedbed Condition Effects

This study showed that site preparation after harvest reduces numbers of cones in cutovers within 30 cm of ground level compared to areas not receiving site preparation. Mean cone numbers in site prepared cutovers, regardless of harvesting season, harvesting method, or stand age were 10 100 cones/ha. In contrast, cutovers without site preparation averaged almost 22 000 cones/ha.

This difference is substantial and is perhaps attributable to site preparation burying cones. Although there was insufficient replication to analyse the data based on machine type, it is conceivable that less severe methods of site preparation such as barrels and chains have a different impact on cone numbers than the more severe methods such as trenching. One difference is that many more cones may be buried or broken apart after severe site preparation than after minimal site preparation.

Predicting Seedling Density and Stocking From Cones

If it were possible to predict seedling density and stocking from cone numbers and distribution on a cutover, the relative success of natural regeneration could be determined. The need for additional treatment would be realized very soon after cutting. As such, areas could be prioritized to receive differential rates of aerial seeding or targeted for fill-in planting or some other regeneration treatment.

Predicting Seedling Density From Cone Numbers

To predict densities of two-year-old seedlings from cone numbers following harvest, it is necessary to know the total number of cones/ha, the proportion that have opened after two years, the number of viable seeds/cone, the proportion of these seeds that actually reach the ground and land on microsites capable of supporting germination, and the mortality rate of jack pine germinants. Some of these data are available from the literature, and are pieced together here as a first approximation to predict two-year jack pine seedling density from the number of cones in a cutover.

Not all cones open in the first year following harvest. In a study of lodgepole pine (*Pinus contorta var. latifolia*) in Alberta, Crossley (1956) found 51% opened cones after the first year. In addition, the majority of these cones were within 30 cm of the ground surface where temperatures were comparatively high due to incoming solar radiation reflecting upward from the soil surface. For jack pine, Lyon and Van Nooten (1958) reported 78% opened cones after two years in cutovers northeast of Thunder Bay, Ontario. After one year, Noakes (1946) reported an average of 75% opened cones in a jack pine cutover near Pembroke, Ontario.

The number of viable seeds per cone is variable. In Minnesota, Roe (1963) showed a range of 17 to 33 viable seeds/cone collected from trees nine to 80 years old. An average of 12 viable seeds/cone was reported by Baker (1980) from one to ten-year-old cones collected from 55 to 80-year-old trees in northeastern Ontario.

It is now critical to know how many of the viable seeds in each cone are actually released. Unfortunately, no data in this regard are available for jack pine, but in Crossley's (1956) study in lodgepole pine only 50% of the total number of viable seeds contained in the cones were actually released and reached the ground.

The number of seeds that germinate and survive through one or two growing seasons varies a great deal. In a study of jack pine reproduction in Saskatchewan, Jameson (1961) reported differential first-year survival of natural jack pine germinants based on thickness of slash. Those germinants underneath slash greater than 15 cm thick had a survival rate of only 2%. Mortality was attributed primarily to damping-off disease as a result of high

humidity under the deep slash. In contrast, germinants only lightly covered (<15 cm) had a survival rate of 64%.

In Manitoba, Walker and Sims (1984) reported 16% survival after two years for viable jack pine seeds sown on specially prepared, optimum microsites surrounded by exclosures to preclude predation by animals. Near Thunder Bay, Ontario, Lyon and Van Nooten (1958) reported a 9% survival rate two years after manually scattering jack pine slash over mineral soil or disturbed duff following harvesting.

After summarizing these results, the following equation was derived:

Number of jack pine seedlings/ha after two years =

Number of cones/ha x (0.54) x (% acceptable microsites/100)

where: number of cones/ha results from a field survey,

0.54 = 75% opened cones after 2 years x 12 viable seeds/cone x 50% seed released x 12% average survival of germinants after 2 years, and

% acceptable microsites/100 = proportion of cutover area suitable for jack pine seed germination (expressed as a decimal percent), assuming even distribution of acceptable microsites throughout the area.

Applying this equation to the minimum (8800) and maximum (126 800) number of cones per treatment combination in this study (Table 1), and assuming an arbitrary average of 30% acceptable germination spots in a cutover, predicted densities for two-year-old jack pine seedlings would range from approximately 1 425 to 20 500 seedlings/ha. These numbers seem to reflect realistic densities of young jack pine stands in northwestern Ontario.

Predicting Seedling Stocking From Cone Numbers

It is necessary to know both seedling stocking and density levels to have a basis for making silvicultural prescriptions. If it is possible to predict stocking levels of, for example, two-year-old seedlings from the distribution of cones in a cutover, more precise silvicultural decisions could be made.

Lyon and Van Nooten (1958) investigated effects of mechanical scarification, brush scattering and direct seeding in a jack pine cutover. Their study showed that three and five cones were needed to produce a two-year-old natural jack pine seedling on stone-free fine sand and gravelly fine sand sites, respectively. This is the reason that five, and a conservative doubling to 10, cones per 4 m^2 were used as minimum stocking standards in Table 2.

Using the most conservative standard of 10 cones/4 m^2 as a measure of successful post-harvest stocking of two-year-old jack pine seedlings, and setting an acceptable minimum stocking of 60% at two years, only three of 11 treatment combinations would result in a successfully stocked stand after two years. These are full-tree logging in old stands in the summer, with or without site preparation, and tree-length logging in old stands in the summer without site preparation (Table 2).

Predicting Seedling Density From Pre-Harvest Cone Loads

If the density of post-harvest two-year-old jack pine seedlings could be predicted pre-harvest, silvicultural decision-making and planning would be enhanced greatly. Results from Baker (1980) show the relationship between cone yields and average stand diameter (Figure 3). Using this relationship in

conjunction with a stand table (to describe diameter distributions) for any particular proposed harvest block, it is possible to estimate pre-harvest cone numbers.

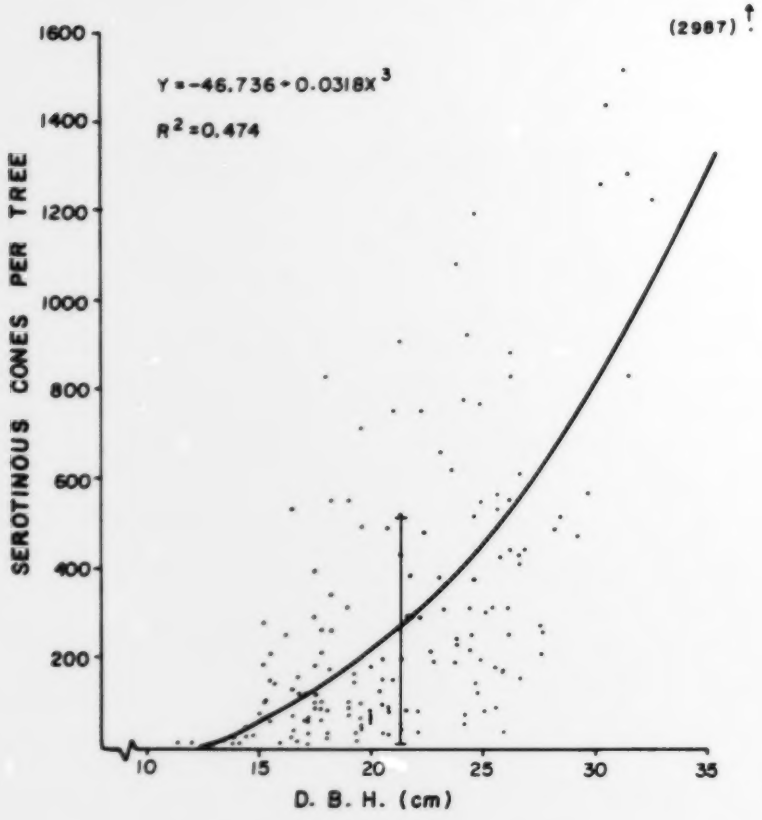

Figure 3. Average number of cones per tree in relation to breast height diameter; 28 to 80-year-old jack pine, northeastern Ontario (from Baker 1980).

For the tree-length harvesting method, the number of cones in the cutover would equal pre-harvest cone numbers because crowns and branches are left on-site. For the full-tree harvesting method, part of the original cone supply will remain on the tree and be dragged to roadside, while the remainder

will be left behind through breakage. Unfortunately, there are no available data relating pre-harvest cone numbers to numbers of cones in a cutover after full-tree logging.

SUMMARY

Cone Numbers

In this study, numbers of cones ranged from a low of approximately 8 800 cones/ha after full-tree logging of old stands in the winter followed by site preparation, to a high of 126 800 cones/ha after tree-length logging in old stands in the summer without site preparation.

Harvesting in older stands (>80 years) resulted in higher numbers of cones in cutovers compared to harvesting younger (<80 years) stands. Subsequent site preparation generally reduced cone numbers, but results were not consistent across all treatments. Summer logging left more cones in the cutover than did winter logging, but lack of data for tree-length logging in the winter somewhat restricts the strength of this observation.

Tree-length harvesting tended to leave more cones behind in the cutovers than did full-tree harvesting, but there was no consistent trend. In some treatments, tree-length harvesting did, indeed, leave more cones, while in other treatments full-tree harvesting resulted in higher cone numbers. Relationships among stand age, season of harvest, harvesting method, and seedbed condition seem to be too complex for a clear conclusion to be reached from this study relative to the amount of jack pine cones remaining in a cutover due to harvesting method alone.

An equation was developed from information contained in the literature to estimate two-year jack pine seedling densities from post-harvest numbers of

jack pine cones. Applying this equation to areas sampled in this study gave intuitively reasonable results. Field testing the equation will improve its reliability.

Cone Distribution and Seedling Stocking

Minimum stocking standards were compiled from published data to relate numbers of cones in cutovers to stocking of two-year-old jack pine seedlings. Applying the most conservative standard (10 cones/4 m^2 quadrat) to results of this study showed that only three of 11 treatments met the minimum stocking requirement of 60%.

These three treatments were (1) full-tree summer logging in old stands without site preparation, (2) full-tree summer logging in old stands with site preparation, and (3) tree-length summer logging in old stands without site preparation. Stocking levels were 61, 67, and 92 percent, respectively.

Using the equation mentioned above to predict jack pine seedling density from the number of cones in a cutover (assuming 30% acceptable microsites), these three treatments would yield 7 938, 7 970, and 20 542 seedlings/ha, respectively, two years after harvesting. These stocking and density levels seem to be high enough to ensure a successful new stand.

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